

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0239 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 6 07/24/00**PART DATA**

<b>PART NAME</b>	<b>PART NUMBER</b>
<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU : REGULATOR, 750 PSIG	MC284-0533-0006
VACCO INDUSTRIES	73664-0006
LRU :	
LRU :	

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

PNEUMATIC HELIUM SUPPLY (PR4). 0.500 INCH DIAMETER INLET, 0.750 INCH DIAMETER OUTLET.

**REFERENCE DESIGNATORS:** PR4 - MPS PNEU REG**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

REGULATES THE PNEUMATIC HELIUM SUPPLY PRESSURE OF 4500 - 900 PSIA DOWN TO 750 PSIG, WHICH IS THE NOMINAL OPERATING PRESSURE FOR THE MPS PNEUMATIC SYSTEM. THE DOWNSTREAM SYSTEM INCORPORATES A RELIEF VALVE TO PREVENT DOWNSTREAM OVERPRESSURIZATION IN EVENT THE REGULATOR FAILS HIGH.

**FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE**

**NUMBER: 03-1-0239-02**

**REVISION#: 6 07/24/00**

**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: REGULATOR, 750 PSIG**

**CRITICALITY OF THIS**

**ITEM NAME: MPS PNEU SUPPLY 750 PSIG REGULATOR (PR4)**

**FAILURE MODE: 1/1**

---

**FAILURE MODE:**

FAILS OPEN/HIGH OUTLET PRESSURE

**MISSION PHASE:**

PL PRE-LAUNCH  
LO LIFT-OFF  
DO DE-ORBIT

**VEHICLE/PAYLOAD/KIT EFFECTIVITY:**

102 COLUMBIA  
103 DISCOVERY  
104 ATLANTIS  
105 ENDEAVOUR

**CAUSE:**

PIECE PART STRUCTURAL FAILURE, CONTAMINATION, BINDING

**CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO**

---

**REDUNDANCY SCREEN**

A) N/A  
B) N/A  
C) N/A

**PASS/FAIL RATIONALE:**

A)

B)

C)

---

**- FAILURE EFFECTS -**

---

**(A) SUBSYSTEM:**

RESULTS IN LOSS OF HELIUM FROM PNEUMATIC HELIUM SUPPLY THROUGH THE RELIEF VALVE UNLESS BOTH HELIUM ISOLATION VALVES ARE CLOSED. THE RELIEF VALVE LIMITS PRESSURE DOWNSTREAM OF THE FAILED REGULATOR TO 850 PSIG.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

HELIUM TRAPPED IN THE ACCUMULATOR OF THE PNEUMATIC SYSTEM SHOULD BE ADEQUATE FOR LO2 PREVALVE CLOSURE AT MECO, AND WILL BE SUPPLEMENTED WHEN THE LEFT ENGINE HELIUM CROSSOVER VALVE (LV10) OPENS AT MECO.

PRIOR TO T-9 MINUTES, EXCESSIVE HELIUM LEAKAGE WILL BE DETECTABLE USING HAZARDOUS GAS DETECTION SYSTEM (HGDS) AND SCREENED PER LCC REQUIREMENTS.

**ASCENT**

IF FAILURE OCCURS DURING THE FIRST FORTY (40) SECONDS OF ASCENT, POSSIBLE OVERPRESSURIZATION OF THE AFT COMPARTMENT (SAFETY FACTOR FOR THE OMS DECK FRAMES DURING ASCENT IS 1.2). THIS IS BASED ON THE DAY OF LAUNCH LOAD INDICATORS NOT TO EXCEED REDLINE (FACTOR OF SAFETY IS 1.4).

**ENTRY**

AT MM303, ALL 6 ENGINE AND THE PNEUMATIC REGULATORS ARE ACTIVATED. BFS CAUTION & WARNING IS ACTIVATED FOR EACH REGULATOR. HARDWARE CAUTION & WARNING (A LEGS ONLY) IS ENABLED DURING DEORBIT PREPS. IN THE EVENT OF THE LOSS OF BFS MONITORING, THE B LEG REGULATORS ARE CLOSED.

THE PNEUMATIC HELIUM REGULATOR IS NOT ACTIVATED DURING THIS TIME PERIOD.

ANALYSIS INDICATES AFT COMPARTMENT OVERPRESSURIZATION (SAFETY FACTOR FOR THE 1307 BULKHEAD DURING ENTRY IS 1.31 IF NO CREW ACTION IS TAKEN) WILL OCCUR IN APPROXIMATELY 17 SECONDS. TRAINING IN THE NORMAL LEAK ISOLATION PROCEDURE WILL ALLOW THE CREW TO REACT TO THE CAUTION AND WARNING SYSTEM IN LESS THAN 15 SECONDS. THE LOWER ENTRY SAFETY FACTORS WILL NOT RESULT IN LOSS OF VEHICLE; HOWEVER, STRUCTURAL DAMAGE WILL LIKELY OCCUR AND WILL REQUIRE THE VEHICLE TO BE TAKEN OUT OF SERVICE FOR THOROUGH INSPECTION AND REFURBISHMENT AS NECESSARY.

**ON THE GROUND**

ON THE GROUND, REACTIVE CONTROL SOFTWARE LOGIC (LPS) TO ISOLATE A FAILED OPEN REGULATOR IS ACTIVE WHEN MPS PNEUMATICS ARE ACTIVE.

**(B) INTERFACING SUBSYSTEM(S):**

SAME AS A.

**(C) MISSION:**

POSSIBLE LAUNCH SCRUB DUE TO LCC VIOLATION.

**(D) CREW, VEHICLE, AND ELEMENT(S):**

POSSIBLE LOSS OF CREW/VEHICLE.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

1R/2 2 SUCCESS PATHS. TIME FRAME - PRELAUNCH, ASCENT, ENTRY

- 1) REGULATOR (PR4) FAILS OPEN/ HIGH OUTLET PRESSURE.
- 2) RELIEF VALVE (RV4) FAILS CLOSED.

RESULTS IN LINE RUPTURE DOWNSTREAM OF PR4. RAPID LOSS OF HELIUM MAY OVERPRESSURIZE THE AFT COMPARTMENT. THE PNEUMATIC HELIUM SUPPLY WILL BE LOST IF THE FAILURE OCCURS WHILE THE ISOLATION VALVES (LV7,8) ARE OPEN (PRELAUNCH THROUGH VACUUM INERTING).

THE ENGINE 1 AND 3 HELIUM SUPPLIES WILL ALSO BE LOST IF THE FAILURE OCCURS WHILE THEIR INTERCONNECT "OUT" VALVES (LV60, 64) ARE OPEN (20 SECONDS AFTER MECO). HELIUM MAY NOT BE AVAILABLE FOR AFT COMPARTMENT PURGE (RTL5 AND TAL ABORT CRITICAL).

IF THE LINE FAILURE OCCURS UPSTREAM OF CV9, HELIUM TRAPPED IN THE ACCUMULATOR LEG OF THE PNEUMATIC SYSTEM SHOULD BE ADEQUATE FOR LO2 PREVALVE CLOSURE AT MECO.

IF THE LINE FAILURE OCCURS DOWNSTREAM OF CV8, LOSS OF HELIUM WILL MAKE REPRESSURIZATION FOR MPS DUMP IMPOSSIBLE. THE PROPELLANT RELIEF SYSTEM WILL PROTECT AGAINST PROPELLANT MANIFOLD RUPTURE. VENTING OF PROPELLANTS DURING AN ABORT ENTRY WILL ALSO CREATE A FIRE/EXPLOSION HAZARD.

DURING ENTRY, VENT DOORS ARE CLOSED TO PREVENT INGESTION OF RCS AND APU GASES. RUPTURE DURING THE TIME PERIOD THAT THE VENT DOORS ARE CLOSED MAY RESULT IN OVERPRESSURIZATION OF AFT COMPARTMENT. VENT DOORS ARE OPENED WHEN VEHICLE VELOCITY DROPS BELOW 2400 FT/SEC.

POSSIBLE LOSS OF CREW/VEHICLE.

---

**-DISPOSITION RATIONALE-**

---

**(A) DESIGN:**

THE HELIUM REGULATOR IS A PILOT OPERATED PRESSURE CONTROL VALVE THAT REGULATES HELIUM INLET PRESSURES FROM 4500 - 900 PSIA TO AN OUTLET PRESSURE BAND OF 705-775 PSIA FOR -0004 AND -0005 CONFIGURATION, 700- 770 PSIG FOR -0006 CONFIGURATION (750 PSI SET POINT). WHEN THE OUTLET PRESSURE FALLS BELOW 715 PSIA, THE BELLOWS/SPRING ASSEMBLY EXPANDS AND FORCES THE PILOT POPPET TO OPEN VIA THE PILOT SHAFT. THIS ALLOWS A PRESSURE DECREASE BEHIND THE MAIN POPPET CAUSING IT TO SLIDE TO THE OPEN POSITION. THE BELLOWS/DAMPER ASSEMBLY SENSES THE OUTLET PRESSURE AND CLOSSES WHEN THE OUTLET PRESSURE EXCEEDS 770 PSIA (765 PSIG FOR -0006 CONFIGURATION).

THE -0005 HELIUM REGULATOR IS IDENTICAL TO THE -0004, EXCEPT AS FOLLOWS: A SLEEVE ORIFICE WAS ADDED TO REDUCE THE FLOWRATE BOTH IN AND OUT OF THE MAINSTAGE DAMPER VOLUME; A NEW MAINSTAGE PISTON SEAL WAS INSTALLED; ACCEPTANCE CRITERIA OF 1740 SCFM OUTLET FLOWRATE WAS IMPOSED (THE -0004

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

CONFIGURATION IS CAPABLE OF FLOWING 1740 SCFM BUT IS NOT PART OF THE ACCEPTANCE CRITERIA).

THE -0006 HELIUM REGULATOR IS SIMILAR TO THE -0005, EXCEPT AS FOLLOWS:

- (1) MAINSTAGE PISTON CONTROL NO LONGER HAS A .010 TO .030 INCH FLOW PASSAGE AND AN ANNULAR FLOW PASSAGE BUT A SINGLE .010 TO .015 INCH ORIFICE MACHINED DIRECTLY INTO THE MAINSTAGE PISTON. THE FLOW PATH IS CONTROLLED BY THIS ORIFICE ONLY.
- (2) THE MAINSTAGE PISTON COIL SPRING IS REPLACED BY A BELLEVILLE SPRING. THE BELLEVILLE IS MADE OF MARAGING 250 STEEL VS. ELGILOY STEEL MATERIAL.
- (3) THE ORIFICE AT THE CONTROLLER IS EDM MACHINED DIRECTLY TO THE CONTROLLER HOUSING RATHER THAN AN ORIFICE INSERT AND IS SMALLER (.005 VS. .030 IN.).
- (4) THE CONTROLLER REFERENCE PRESSURE IS BASED ON AN AMBIENT/VACUUM VENT RATHER THAN A 78.5 PSIA ABSOLUTE REFERENCE PRESSURE. THE BELLOWS REFERENCE VENT PORT IS PROTECTED BY A 120 ABSOLUTE MICRON FILTER. THE VENTED BELLOWS PROTECTS THE REGULATOR FROM FAIL OPEN CONDITION IN THE EVENT OF BELLOWS LEAKAGE.

UNDER NORMAL REGULATOR OPERATION, WHEN THE OUTLET PRESSURE IS LOWERED, THE EXTERNAL PRESSURE ON THE BELLOWS ASSEMBLY DECREASES AND ALLOWS THE BELLOWS TO EXPAND. THIS RAPIDLY MOVES THE PILOT SHAFT AGAINST THE PILOT POPPET AND FORCES IT TO OPEN. THIS ALSO DECREASES THE BACKSIDE PRESSURE ON THE MAIN POPPET AND ALLOWS IT TO OPEN A FLOW PATH FROM THE INLET TO THE OUTLET. SEVERAL CONDITIONS COULD ALLOW THE REGULATOR TO FAIL HIGH:

BELLOWS LEAKAGE (-0004 AND -0005 CONFIGURATION) - THE INCONEL 718 BELLOWS ASSEMBLY IS HERMETICALLY PRESSURE SEALED (WITH FREON 14) TO 78.5 PSIA. LEAKAGE OF THE BELLOWS ASSEMBLY CAUSES A PRESSURE BIAS WHICH RESULTS IN REGULATOR FAILING OPEN. TO PRECLUDE THIS, THE BELLOWS ASSEMBLY IS TESTED FOR LEAKAGE ( $1 \times 10^{-7}$  SCCS) AND FOR LONG TERM (8 HOUR) LOAD VARIANCE PRIOR TO ASSEMBLY IN THE REGULATOR HOUSING. IN THE -0006 CONFIGURATION, THE BELLOWS IS VENTED TO PRECLUDE A WIDE OPEN FAILURE WITH A BELLOWS LEAK CONDITION.

RING GUIDE CONTAINMENT - THE MAIN POPPET RING GUIDES THE POPPET FROM THE OPEN TO CLOSED POSITION. THE RING IS MADE FROM VESPEL SP-21 TO MINIMIZE BINDING. THE MAIN POPPET ASSEMBLY PROVIDES 100% CONTAINMENT OF THE RING.

POPPET SEAT LEAKAGE - THE MAIN AND PILOT POPPETS ARE PROTECTED FROM CONTAMINATION BY AN UPSTREAM 25 MICRON ABSOLUTE RATED FILTER ASSEMBLY. THE REGULATOR IS ASSEMBLED CLEAN TO LEVEL 100A AND THE HELIUM SUPPLIED TO THE ORBITER IS FILTERED BY GROUND SYSTEMS. A 125 MICRON FILTER IS PROVIDED TO PROTECT THE PILOT POPPET FROM CONTAMINATION.

POPPET/PISTON BINDING - THE POPPETS AND THE DAMPER PISTON ARE PROTECTED FROM BINDING BY THE USE OF MOLY-KOTE DRY LUBRICANT FOR THE ALUMINUM PARTS AND BY THE USE OF VESPEL SP-21 RINGS ON THE MAIN POPPET AND DAMPER ASSEMBLIES.

CLOGGED FILTER - THE PILOT FILTER (APPROXIMATELY 125 MICRON) PREVENTS CONTAMINATION FROM ENTERING THE PILOT CONTROL SECTION OF THE REGULATOR. IF THE FILTER BECOMES CLOGGED, THE FLOW TO THE PILOT SECTION DECREASES. THIS

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

PREVENTS THE MAIN POPPET FROM CLOSING COMPLETELY OR RESPONDING SLOWLY. EITHER OF THESE CONDITIONS INCREASES THE OUTLET PRESSURE. THE HELIUM IS FILTERED BY THE GROUND SYSTEM AND BY AN UPSTREAM SYSTEM FILTER (25 MICRONS ABSOLUTE) BEFORE IT ENTERS THE REGULATOR INLET.

MAIN POPPET COIL SPRING FAILURE (-0004 AND -0005 CONFIGURATION) - FAILURE OF THE MAIN POPPET SPRING WOULD PREVENT THE REGULATOR FROM CLOSING RAPIDLY. THE MAIN POPPET SPRING IS DESIGNED AGAINST FAILURE BY THE USE OF 302 CRES MATERIAL WHICH EXHIBITS GOOD FATIGUE ENDURANCE PROPERTIES.

MAIN POPPET BELLEVILLE SPRING FAILURE (-0006 CONFIGURATION). FAILURE OF THE MAIN POPPET BELLEVILLE SPRING WOULD PREVENT THE REGULATOR FROM CLOSING RAPIDLY. THE BELLEVILLE SPRING IS MADE OF MARAGING 250 STEEL.

PILOT POPPET COIL SPRING FAILURE - RESULTS IN FAILURE OF THE PILOT POPPET TO RETURN TO THE CLOSED POSITION. THIS WOULD RESULT IN WIDE OPEN PILOT FLOW (ORDER OF 200 SCFM). THE SPRING IS CONSTRUCTED OF 302 CRES.

PILOT POPPET BINDING - BINDING WOULD RESULT IN FAILURE OF THE PILOT POPPET TO RETURN TO THE CLOSED POSITION. THIS WOULD RESULT IN WIDE OPEN PILOT FLOW (ORDER OF 200 SCFM). THE PILOT POPPET IS CONSTRUCTED OF POLYIMIDE SP-21 (DUPONT) TO PRECLUDE BINDING.

**(B) TEST:**

ATP

EXAMINATION OF PRODUCT

PROOF PRESSURE (9250 PSIG INLET, 1950 PSIG OUTLET, -0005/-0006)

INTERNAL LEAKAGE, INLET TO OUTLET (4500 PSIG INLET, 760/765 PSIG OUTLET, AMBIENT AND LOW TEMPERATURE (-80 DEG F))

EXTERNAL LEAKAGE (4500 PSIG INLET, 850 PSIG OUTLET, AMBIENT)

FUNCTIONAL

AMBIENT AND LOW TEMPERATURE (-80 DEG F)

REGULATION

INLET PRESSURE 900 TO 4500 PSIG

TRANSIENT RESPONSE

(SLAM START WITH FOLLOWING INITIAL CONDITIONS)

INLET PRESSURE 4500 AND 2500 PSIG

OUTLET PRESSURE 15 PSIG

FLOW TESTS (4500 TO 900 PSIG INLET PRESSURE, AMBIENT)

PURGE SEQUENCE 4 (260 TO 845 SCFM)

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

ENGINE START COMMAND (260 TO 720 SCFM)

MECO (WITH AND WITHOUT INTERCONNECT, 260 TO 1896 SCFM)

CERTIFICATION

TWO UNITS CERTIFIED FOR -0004. ADDITIONAL DELTA QUAL TEST WAS CONDUCTED FOR THE -0005 AND -0006 CONFIGURATION AS INDICATED BELOW.

VIBRATION TEST

TRANSIENT

5 TO 35 HZ AT +/- 0.25 G IN EACH OF THREE AXES

RANDOM

4.4 HOURS IN EACH OF THREE ORTHOGONAL AXES WHILE THE REGULATOR IS CONTROLLING THE OUTLET PRESSURE FROM 715 TO 770 PSIA WITH THE INLET PRESSURE AT 4500 AND 900 PSIG.

PERFORM AMBIENT INTERNAL AND EXTERNAL LEAKAGE, AND FUNCTIONAL TESTS IN EACH AXIS.

DESIGN SHOCK

PER MIL-STD-810 IN EACH OF THREE AXES.

PERFORM AMBIENT INTERNAL AND EXTERNAL LEAKAGE, AND FUNCTIONAL TESTS IN EACH AXIS.

THERMAL CYCLE TEST (ONE UNIT ONLY, INLET AT 750 PSIG AND NO FLOW)

CYCLE FROM -150 DEG F TO +250 DEG F: 3 CYCLES

UPON COMPLETION, AMBIENT INTERNAL AND EXTERNAL LEAKAGE, AND FUNCTIONAL TESTS ARE PERFORMED.

LIFE CYCLE TESTS

SLAM START (WITHIN 8 MILLISECONDS)

250 CYCLES

INITIAL INLET PRESSURE 4500 PSIG

INITIAL OUTLET PRESSURE 0 PSIG

250 CYCLES

INITIAL INLET PRESSURE 2000 PSIG

INITIAL OUTLET PRESSURE 0 PSIG

ULLAGE TRANSIENT (1000 TO 1200 CUBIC INCHES)

5000 CYCLES

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

INITIAL INLET PRESSURE 4500 AND 900 PSIG  
INITIAL OUTLET PRESSURE LOCKUP (715 TO 775 PSIA)

AMBIENT INTERNAL LEAKAGE TEST AFTER EACH 500 CYCLES

AMBIENT EXTERNAL LEAKAGE TEST AFTER 2500 CYCLES

BLOWDOWN (FLOW RATE NOT TO EXCEED 1.0 LB/SEC)  
1 CYCLE (INLET PRESSURE 4500 TO 900 PSIG)

FLOW TEST (2 UNITS)  
108 CYCLES (800 AND 600 SCFM, INLET PRESSURE 4500 TO 900 PSIG)

UPON COMPLETION OF LIFE CYCLE TEST PERFORM AMBIENT AND LOW TEMPERATURE  
INTERNAL AND EXTERNAL LEAKAGE, AND LOW TEMPERATURE FUNCTIONAL TESTS.

BURST TEST (ONE UNIT ONLY)  
18,000 PSIG INLET, 3,400 PSIG OUTLET

DELTA CERTIFICATION FOR -0005 CONFIGURATION - THE PREVIOUS RESULTS FOR THE -0004  
APPLY TO THE -0005 CONFIGURATION. THE ENGINE HELIUM PURGE SYSTEM REQUIREMENT  
HAS BEEN DEEMED TO BE MORE SEVERE THAN THE PNEUMATIC SYSTEM. THEREFORE,  
THE ENGINE PURGE SYSTEM REQUIREMENTS WERE USED TO CERTIFY THE REGULATOR  
FOR BOTH APPLICATIONS. SELECTED PNEUMATIC SYSTEM/REGULATOR TESTS WERE  
PERFORMED TO DEMONSTRATE THIS RATIONALE.

MPTA 12 MISSION (48 MISSION LIFE) CERTIFICATION TEST

TO DEMONSTRATE ADEQUATE REGULATOR LIFE CYCLE CAPABILITY, TWO MPTA  
REGULATORS WERE SELECTED AND TESTED IN THE ENGINE #3 HELIUM PURGE SYSTEM.  
THE ENGINE #3 SYSTEM WAS USED, SINCE IT IS IDENTICAL TO THE VEHICLE SYSTEM AS TO  
BASIC ROUTING AND LINE DIAMETERS. MINOR DEVIATIONS AS TO MECHANICAL FITTING  
AND MINOR BEND RADII EXISTS. THE REGULATOR PANELS CONTAINING THE REGULATOR,  
RELIEF VALVE, AND CHECK VALVE ARE IDENTICAL TO THE FLIGHT CONFIGURATION. IT  
WAS DETERMINED FROM THE FLOW TEST OF THE PNEUMATIC REGULATOR/SYSTEM (S/N  
009) AND ALL FOUR ENGINE HELIUM REGULATORS TESTED IN ENGINE #3 SYSTEM, THAT S/N  
011 AND S/N 019 REGULATORS EXHIBITED THE GREATEST OSCILLATION TENDENCIES AND  
WERE USED AS TEST ARTICLES. THE ENGINE TEST USED TO SELECT THE REGULATORS  
SHOWED MINOR DIFFERENCES BETWEEN REGULATORS (ALL STABLE). THE S/N 011 AND  
S/N 019 OSCILLATIONS WERE NOT SIGNIFICANT AND DID NOT EXCEED THE 40 PSI DOUBLE  
AMPLITUDE ALLOWABLE LIMIT.

EVEN THOUGH THE PNEUMATIC REGULATOR/SYSTEM WAS TESTED, THE  
REPRESSURIZATION FLOW CONDITIONS DURING ENTRY WERE NOT CONDUCTED. AT THE  
TIME, IT WAS THE OPINION THAT THIS CONDITION WAS NOT CRITICAL AND THE COMPLEXITY  
OF CONDUCTING THIS TEST DID NOT SEEM WARRANTED. ADDITIONAL FEED SYSTEM  
VALVING AND 20 PSIG REGULATOR SYSTEM WOULD HAVE HAD TO BE OPERATED TO  
CONDUCT THIS TEST.

EACH MISSION SIMULATION CONSISTED OF AN EQUIVALENT OF TWO ORBITER  
PROCESSING FACILITY (OPF) FLIGHT READINESS TESTS (FRTS), TWELVE LAUNCH PAD

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

FRTS, ASCENT MISSION FLOW PROFILE AND BLOWDOWN FOR A TOTAL OF 48 MISSION SIMULATIONS. OVER 500 PURGE SEQUENCE 4/ENGINE START COMMAND AND MECO FLOW SEQUENCES WERE CONDUCTED. THE FIRST 30 MISSION SIMULATIONS WERE CONDUCTED WITH AN SSME INSTALLED. THE BALANCE OF 10 WAS CONDUCTED USING AN ENGINE HELIUM SYSTEM SIMULATOR (ENGINE HELIUM LINES AND VALVES WITH ORIFICES TO CONTROL FLOW RATES). THE PREVIOUS MPTA TESTING WAS DETERMINED TO BE EQUIVALENT TO EIGHT MISSIONS FOR A TOTAL OF 48 MISSIONS. THE REGULATOR FLOW BEHAVIOR FROM THE FIRST FLOW TEST TO THE LAST WERE FOR ALL VIRTUALLY IDENTICAL. SELF DAMPING OSCILLATIONS OCCURRED ON 16 OUT OF 50 MECOS WHEN THE 4400 PSIA PNEUMATIC SYSTEM WAS INTERCONNECTED "IN" TO THE ENGINE #3 SYSTEM.

**OV-103 AND OV-104 REGULATOR FLOW TESTS**

OV-103 AND OV-104 REGULATORS, USING THE SAME INSTRUMENTATION, INSTRUMENTATION INSTALLATION, AND RECORDING SYSTEM USED ON MPTA (HI-FREQUENCY KULITE PRESSURE TRANSDUCERS), WERE TESTED TO DETERMINE THEIR FLOW CHARACTERISTICS. THE TEST CONSISTED OF TESTING BOTH THE PNEUMATIC (ONE) AND ENGINE SYSTEM REGULATORS (SIX). THE TEST DUPLICATED THE FLOW CONDITIONS EXPERIENCED DURING BOTH GROUND AND FLIGHT OPERATIONS. THE TESTS WERE PRIMARILY RUN WITH 4000 TO 4500 PSIA HELIUM BECAUSE PRESSURE OSCILLATIONS ON THE VENDOR TEST STAND WERE OBSERVED PRIMARILY AT 4000 PSIA. THE VENDOR TEST STAND DATA ALSO INDICATED THAT OSCILLATION FREQUENCY AND MAGNITUDE DECAYED WITH DECREASED INLET PRESSURES AND WITH HIGHER FLOW RATE CONDITIONS (ABOVE 230 SCFM FLOW).

THE PNEUMATIC REGULATOR WAS TESTED AT THE 322 TO 500 SCFM RANGE CONSISTENT WITH ITS NORMAL FLOW CONDITION. EACH ENGINE HELIUM SYSTEM WAS TESTED FOR THE PURGE SEQUENCE FOUR, ENGINE START COMMAND, MECO, AND MECO WITH "INTERCONNECT" FLOWS. THESE FLOW CONDITIONS HAVE BEEN DETERMINED TO BE THE CRITICAL CONDITIONS THAT MUST BE SATISFIED TO DETERMINE THE STABILITY CHARACTERISTICS OF THE REGULATORS. THESE FLOW CONDITIONS WERE RUN AT LEAST TWICE ON EACH ENGINE HELIUM SYSTEM.

THE OV-103 AND OV-104 TESTS RESULTED IN THE REJECTION OF 9 OF 12 ENGINE REGULATORS DUE TO PRESSURE OSCILLATIONS EXCEEDING THE 40 PSI DOUBLE AMPLITUDE ALLOWABLE LIMIT. FOR OV103, UNACCEPTABLE REGULATORS WERE REMOVED AND REPLACED WITH REGULATORS WHOSE OSCILLATIONS ARE LESS THAN THE 40 PSI REQUIREMENT. FOR OV104, ALL UNACCEPTABLE REGULATORS WERE REMOVED AND WILL BE REPLACED WITH ACCEPTABLE REGULATORS WHEN AVAILABLE.

DELTA QUAL TEST FOR -0006 CONFIGURATION - PREVIOUS RESULTS OF THE -0004 AND -0005 QUAL TEST APPLY IN PART OR DIRECTLY TO THE CERTIFICATION OF THE -0006 CONFIGURATION AS INDICATED IN THE CERTIFICATION REQUIREMENTS. VIBRATION DELTA QUAL TEST CONSISTS OF RANDOM VIBRATION TEST OF .5 HOURS/AXIS (2 ORTHOGONAL AXES) AFTER 50 FLIGHT/MISSION FLOW CYCLE COMPLETION AND AGAIN AFTER 100 FLIGHT/MISSION CYCLES COMPLETION. DURING VIBRATION TEST, THE REGULATOR MAINTAINED OUTLET PRESSURE AT 715 TO 765 PSIG WITH 100 +/- 50 SCIM FLOW AND WITH AN INLET PRESSURE OF 4500 TO 3000 PSIG. THE ORIGINAL -0006 CONFIGURATION LIFE CYCLE TEST CONSISTS OF 5200 PRESSURE SLAMS AND 32,300 FLOW DEMAND CYCLES. IN 1997 AN ADDITIONAL 11,600 SLAM CYCLES WERE ADDED TO BRING THE TOTAL NUMBER OF SLAM CYCLES TO 16,800 CYCLES (100 MISSIONS)

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

INCOMING MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION.

CONTAMINATION CONTROL

ALL PARTS ARE CLEANED TO LEVEL 100A PRIOR TO ASSEMBLY.

ASSEMBLY/INSTALLATION

DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. PARTS ARE VISUALLY INSPECTED AT 10X TO 40X MAGNIFICATION, INCLUDING CRITICAL POPPET, SLEEVE SURFACES, AND SEALS. TORQUE AND LOCKWIRE OF FASTENERS ARE VERIFIED PER REQUIREMENTS. MANDATORY INSPECTION POINTS ARE ESTABLISHED TO ENSURE THAT CORRECT MANUFACTURING PROCEDURES ARE FOLLOWED. ELECTRO CHEM-ETCHED MARKING IS VERIFIED PER SPECIFICATION.

CRITICAL PROCESSES

PART PASSIVATION AND WELDING PROCESSES ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

HELIUM LEAK CHECK IS VERIFIED BY INSPECTION.

TESTING

ATP, INCLUDING PROOF PRESSURE TEST, IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT IS VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**

QUALIFICATION

DURING QUALIFICATION TESTING (BLOWDOWN TESTING), THE OUTLET PRESSURE WAS RECORDED AT 780 PSIG ON THE 67TH CYCLE. (REFERENCE CAR AB1431). MAXIMUM ALLOWED IS 760 PSIG. THE REGULATOR WAS DISASSEMBLED AND THE SENSOR BELLOWS WAS FOUND TO HAVE CRACKS IN THE SECOND DIAPHRAGM ROOT WELD AREA. ANALYSIS CONCLUDED THAT THE REGULATOR WAS OVERPRESSURIZED WHILE MOUNTED ON THE ATP TEST STAND FOR A LIFE CYCLE FLOW TEST. THE SUPPLIER CAUTIONED TEST OPERATORS TO FOLLOW THE TEST PROCEDURES CAREFULLY. THE TEST STAND WAS MODIFIED BY ADDING A 1000 PSIG BURST DISC IN THE SYSTEM DOWNSTREAM OF THE REGULATOR TO ELIMINATE THE POSSIBILITY OF OVERPRESSURIZING THE TEST SPECIMEN.

ATP

DURING ATP, REGULATOR LOCK-UP WAS MEASURED AT 786 PSIG AT 1700 PSIG INLET PRESSURE (REFERENCE CAR A6469). MAXIMUM ALLOWABLE IS 760 PSIG. ANALYSIS

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

CONCLUDED THAT THE COOLING AND SHRINKING FOLLOWING THE CLOSEOUT WELD WAS AFFECTING THE BELLOWS ASSEMBLY PRELOAD DUE TO INADEQUATE CLEARANCE BETWEEN THE END CAP AND BELLOWS ASSEMBLY. SHIMMING CORRECTED THE CLEARANCE AND NEW REGULATORS WILL BE BUILT TO THE NEW REQUIREMENTS.

DURING ATP, THE REGULATOR S/N 004 LOCK-UP OCCURRED AT 762 PSIG (REFERENCE CAR A6750). MAXIMUM LOCK-UP PRESSURE IS 760 PSIG. FAILURE ANALYSIS ATTRIBUTED THE HIGH LOCK-UP TO ADJUSTMENT OF THE MAINSTAGE TO THE HIGH SIDE OF THE REGULATOR'S OPERATING BAND AND A FURTHER RISE OCCURRING DURING WELDING THE CLOSURE. A DESIGN CHANGE WAS APPROVED FOR THE NEW CONFIGURATION (MC284-0533-0002) WHICH INCLUDED A MATERIAL CHANGE IN THE SENSOR RETAINER ASSEMBLY AND MAIN PISTON SEAL, DIMENSIONAL AND BELLOWS CHANGES. THE REGULATOR WAS WAIVED FOR MPTA TESTING ONLY.

DURING ATP OF THE MPTA ENGINE #3 PANEL ASSEMBLY AT DOWNEY, THE HELIUM REGULATOR TO ENGINE #3 EXCEEDED THE OUTLET PRESSURE LIMIT OF 780 PSIG (REFERENCE CAR A7080). LOCK-UP WAS RECORDED AT 825 PSIG. FAILURE ANALYSIS WAS PERFORMED AND THE RING INSERT WAS SEEN TO BE DISPLACED; IT MOVED TOWARD THE POPPET OUT OF THE PISTON RETAINING GROOVE. A SECOND FAILURE OCCURRED DURING ATP SLAM START TEST, WHERE THE OUTLET PRESSURE EXCEEDED THE 760 PSIG MAXIMUM PRESSURE SPIKE (REFERENCE CAR A7718). TEARDOWN FOUND THAT THE RING INSERT WAS MISSING. LACK OF 100 % CONTAINMENT OF THE RING INSERT ALLOWED IT TO BE BLOWN OUT OF THE REGULATOR DURING THE SLAM START TEST. THE RING INSERT/PISTON AREA WAS REDESIGNED TO PROVIDE 100% CONTAINMENT BY THE POPPET GUIDE TO PREVENT RING INSERT DISPLACEMENT.

DURING ATP, THE REGULATOR FAILED TO MEET THE LOCK-UP REQUIREMENT OF 10 SCIM MAXIMUM LEAKAGE WITH A 900 PSIG INLET PRESSURE AT -150 DEG F (REFERENCE CAR A7947). LEAKAGE WAS CAUSED BY HEAT SHRINKAGE FROM THE TIG SEAL WELD OPERATION BETWEEN THE SLEEVE ASSEMBLY AND THE HOUSING. THIS SHRINKAGE PULLED THE JOINT TO THE SIDE OF THE INITIAL WELD AND CAUSED ECCENTRICITY OF THE UPPER GUIDE. THE SUPPLIER'S WELDING OPERATION WAS REVISED TO TACK WELD THE SLEEVE/HOUSING JOINT IN FOUR PLACES AT 90 DEG PRIOR TO THE FINISH WELD. THIS WILL MAINTAIN SLEEVE CONCENTRICITY DURING AND AFTER THE CLOSEOUT WELD.

DURING ATP SLAM START PRESSURE REGULATION TEST, THE AVERAGE OUTLET PRESSURE WAS 765 PSIG (REFERENCE CAR A9329). MAXIMUM PRESSURE ALLOWABLE IS 760 PSIG. ADDITIONAL TESTING INDICATED THAT THE BEARING RING GUIDE CLEARANCE MUST BE HELD TO A CLOSER TOLERANCE TO CONSISTENTLY MEET REGULATOR OUTPUT REQUIREMENTS. THE SUPPLIER CHANGED THE POPPET ASSEMBLY DRAWING TO CONTROL BEARING RING GUIDE CLEARANCE TO BE WITHIN .0015 - .0018 INCHES.

DURING ATP, THE REGULATOR HAD INTERNAL LEAKAGE GREATER THAN 100 SCIM (REFERENCE CAR AB6737). MAXIMUM ALLOWED IS 10 SCIM DURING LOCK-UP. FAILURE ANALYSIS FOUND THAT THE MAIN PISTON SEAL WAS CRACKED DUE TO A MATERIAL DEFECT. THE LEAKAGE FAILURE FOLLOWED THE PROOF TEST WHICH PROVIDED THE STRESS TO DAMAGE THE WEAK AREA OF THE SEAL MATERIAL. THE SEAL WAS REPLACED AND THE UNIT PASSED ATP. THE SUPPLIER IMPOSED AN INSPECTION OF ALL SEALS AT 10X MAGNIFICATION PRIOR TO ASSEMBLY.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

DURING ATP, THE REGULATOR LOCK-UP PRESSURE EXCEEDED THE 760 PSIG ALLOWABLE (REFERENCE CAR AB6851). NO SIGNIFICANT CONTAMINATION WAS FOUND. THE PILOT SEAT WAS RELAPPED AND UPON REASSEMBLY, NO FURTHER LEAKAGE WAS OBSERVED. THE EXISTING ATP IS SUFFICIENT TO SCREEN FOR THIS TYPE OF FAILURE MODE.

DURING ATP AT DOWNEY OF A PNEUMATIC PANEL, THE REGULATOR FAILED TO LOCK-UP UNTIL IT EXCEEDED THE MAXIMUM ALLOWABLE PRESSURE AT INLET PRESSURES BELOW 950 PSIG (REFERENCE CAR AB8383). LOCK-UP WAS NORMAL AT HIGHER INLET PRESSURES. ANALYSIS CONCLUDED THAT CONTAMINATION TEMPORARILY CAUSED THE LEAKAGE AT THE MAIN POPPET. THE TEST STAND WAS ALSO DETERMINED TO HAVE A LOW FLOW CAPACITY REGULATOR WHICH COULD NOT OPEN THE MAIN POPPET TO DISLodge THE PARTICLE AT LOW INLET PRESSURES. THE TEST STAND WAS CORRECTED WITH A HIGHER FLOW CAPACITY.

DURING ATP PROOF TEST, INTERNAL LEAKAGE WAS OBSERVED (REFERENCE CAR AC3666). THE MINOR LEAKAGE PAST THE MAIN SEAT WAS DUE TO ROUGHNESS OF THE VESPEL SEAT IN THE AREA WHICH INTERFACES WITH THE POPPET. AFTER REPLACEMENT OF THE MAIN SEAT, THE REGULATOR PASSED ATP. ATP WILL SCREEN FOR THIS TYPE OF FAILURE MODE.

DURING ATP, INTERNAL LEAKAGE WAS OBSERVED ON TWO REGULATORS AT INLET PRESSURES BELOW 1000 PSIG (REFERENCE CAR AD3951). A SIMILAR FAILURE OCCURRED AT NSTL WHERE THE REGULATOR FAILED TO LOCK-UP AT INLET PRESSURES BELOW 2000 PSIG (REFERENCE CAR AD3761). INVESTIGATION CONCLUDED THAT THE INTERNAL LEAKAGE WAS CAUSED BY THE LACK OF MAINSTAGE DAMPER CLEARANCE WITH THE MAIN/PILOT POPPET VESPEL SEAT BEING WORN/SCORED. THE MANUFACTURER HAS BEEN INSTRUCTED TO CONTROL THE MAINSTAGE DAMPER CLEARANCE ON NEW AND REFURBISHED REGULATORS. THESE CARS ARE EXPLAINED FOR ALL VEHICLES, ALL FLIGHTS.

**FIELD**

DURING CHECKOUT OF MPTA ENGINE #2 HELIUM PURGE REGULATOR, THE REGULATOR OUTLET PRESSURE ROSE TO 1000 PSI (REFERENCE CAR AB0523). OUTLET PRESSURE SHOULD BE WITHIN 715 - 775 PSIA. A SIMILAR FAILURE OCCURRED ON THE ENGINE #3 REGULATOR AT DOWNEY DURING ATP OF THE MPTA (REFERENCE CAR A7070). UPON DISASSEMBLY, A LARGE METALLIC PARTICLE (300 CRES) WAS FOUND WEDGED BETWEEN THE POPPET AND THE SEAT SURFACE, PREVENTING THE POPPET FROM CLOSING. THE SOURCE OF THE PARTICLE WAS ATTRIBUTED TO CONTAMINANTS INTRODUCED INTO THE SYSTEM DURING REWORK OR FROM CONTAMINATION IN THE PNEUMATIC SYSTEM DOWNSTREAM OF THE FILTER ELEMENT. ON OV-102 AND SUBS, THE PNEUMATIC PANELS WERE INSPECTED FOR CONTAMINATION AND WERE WITHIN CLEANLINESS REQUIREMENTS. INSPECTION OF STOCK ELBOW AND TEE FITTINGS USED ON THE MPTA CONFIGURATION REVEALED BURRS AND INCOMPLETELY DRILLED HOLES. THE FITTINGS WERE REJECTED AND THE MANUFACTURER WAS ALERTED TO THE PROBLEM OF QUALITY ASSURANCE.

DURING LEAK CHECK OF A REPAIRED LINE ON OV-102, THE PNEUMATIC REGULATOR OUTLET PRESSURE WAS MEASURED AT 830 - 855 PSIG (REFERENCE CAR AB2616). MAXIMUM ALLOWED IS 760 PSIG. A SIMILAR FAILURE OCCURRED WHILE INSTALLED ON MPTA ENGINE PANEL #1, THE REGULATOR HAD EXCESSIVE INTERNAL LEAKAGE IN THE LOCK-UP MODE (REFERENCE CAR AB6308). INVESTIGATION FOUND TEFLON AND METALLIC

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

PARTICLES LODGED AT THE MAIN POPPET/SEAT. CONTAMINATION WAS ATTRIBUTED TO THE PNEUMATIC TEST PANELS. MPS PNEUMATIC PANEL ASSEMBLY PROCEDURE WAS REVISED TO PROVIDE BLOWDOWNS AND/OR CLEANLINESS VERIFICATION TO LEVEL 100A. ADDITIONAL CLEANLINESS CONTROL AND VERIFICATION FOR THE HELIUM FILTER HAS BEEN IMPOSED AT THE SUPPLIER.

DURING SYSTEM CHECKOUT OF OV-099, THE REGULATOR ON ENGINE #3B PANEL WAS REGULATING HIGH (REFERENCE CAR AC4148). THE PRELIMINARY ASSESSMENT INDICATED THAT THE BELLOWS WAS LEAKING; HOWEVER, AFTER EXTENSIVE INVESTIGATION, NO HOLE WAS LOCATED. THE BELLOWS WAS SCRAPPED AND THE REGULATOR PASSED ATP WITH A NEW BELLOWS ASSEMBLY. NO OTHER CORRECTIVE ACTION WAS TAKEN SINCE THIS WAS CONSIDERED AN ISOLATED OCCURRENCE.

**INTERIM CLOSEOUTS**

IN THE DECEMBER 1986 TO MAY 1987 TIME FRAME, THREE REGULATORS FAILED WIDE OPEN DURING PRE-ATP OR ATP AT THE SUPPLIER (REFERENCE CAR AD1643). THE FAILURE WAS CAUSED BY A FATIGUE CRACK IN THE HEAT AFFECTED ZONE OF THE PARENT METAL PROPAGATING THROUGH THE WALL OF THE BELLOWS. ALL THE FAILURES OCCURRED ON AN OVER-SIMPLIFIED TEST STAND WHICH WAS ACTIVATED IN NOVEMBER 1986 AND UTILIZED SMALLER DIAMETER LINES THAN THOSE USED ON THE VEHICLE AND ON THE ORIGINAL ACCEPTANCE TEST STAND (DAMAGED EARLIER IN A BUILDING COLLAPSE). TESTING HAS BEEN CONDUCTED AT KSC, MPTA, AND SUPPLIER TO CHARACTERIZE REGULATOR OSCILLATIONS DURING OPERATIONAL DUTY CYCLES. A NEWLY DESIGNED TEST STAND WAS BUILT TO CORRECTLY SIMULATE THE VEHICLE.

- 1) ENGINEERING EVALUATION TESTS AND A 12 MISSION (48 MISSION TEST) REGULATOR CERTIFICATION TEST PROGRAM WERE CONDUCTED ON MPTA. THIS TEST PROGRAM RESULTED IN ESTABLISHMENT OF A 40 PSI (PEAK TO PEAK) REGULATOR OUTLET PRESSURE OSCILLATION ACCEPTANCE REQUIREMENT.
- 2) THE REGULATORS ON THE VEHICLES HAVE BEEN TESTED TO SCREEN THEM TO THE NEW ATP REQUIREMENT. REGULATORS THAT DID NOT MEET REQUIREMENTS WERE REPLACED (PASSED NEW ATP REQUIREMENT).
- 4) ON THE GROUND, REACTIVE CONTROL SOFTWARE LOGIC (LPS) TO ISOLATE A FAILED OPEN REGULATOR IS ACTIVE WHEN PERSONNEL ARE IN THE AFT FUSELAGE.

DURING OMI TESTING OF OV-104, ENGINE #1 REGULATORS ON LEGS A (S/N 17) AND B (S/N 21) EXCEEDED THE MAXIMUM ALLOWABLE LEAKAGE, 10 SCIM, WITHIN FIVE MINUTES. AFTER ADDITIONAL TESTING, IT WAS DETERMINED THAT ONLY REGULATOR S/N 17 WAS LEAKING. S/N 17 WAS RETURNED TO THE VENDOR WHERE THE LEAKAGE COULD NOT BE REPRODUCED. THE VENDOR REPLACED THE PISTON, POPPET, SLEEVE, CAPSULE AND SEAT ASSEMBLIES. AFTER INSTALLATION INTO OV-104, S/N 17 EXCEEDED 790 PSIA AFTER 47 SECONDS OF ACTIVATION (REFERENCE CAR KB0592). THE REGULATOR UNDERWENT SLAM TESTS AT THE VENDOR TO BETTER REPRESENT THE VEHICLE OPERATIONS; HOWEVER IT STILL FUNCTIONED WITHIN SPEC AND NO LEAKAGE WAS OBSERVED. THE VALVE WAS RETURNED TO SERVICE.

SEVERAL DIFFERENT 750 PSIA REGULATORS EXHIBITED OUT OF SPEC OSCILLATORY BEHAVIOR (REFERENCE CAR AD4281). FAILURES OCCURRED DURING ATP ON THE

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

SUPPLIER'S TEST STAND AND SPECIAL TEST SEQUENCES ON THE MPTA AND OV-103 RUN IN RESPONSE TO CAR AD1643 (BELLOWS FAILURE). ONE OF THESE REGULATORS HAS GONE UNSTABLE AFTER BEING SCREENED AS ACCEPTABLE. DESIGN CHANGES TO THE REGULATOR WERE SUBMITTED TO INCORPORATE A SMALLER DIAMETER ORIFICE AND A DIFFERENT PISTON SEAL.:

REFER TO RATIONALE ITEMIZED IN CAR AD1643 (REGULATOR BELLOWS FAILURE).

- 1) THESE REGULATORS EXHIBITED OUTLET PRESSURE OSCILLATIONS OF APPROXIMATELY 120 PSI PEAK TO PEAK. BELLOWS FAILURE OCCURRED ON REGULATORS EXHIBITING OUTLET PRESSURE OSCILLATIONS SEVERAL TIMES GREATER.
- 2) NASA/JSC TEST DEMONSTRATED THAT AN OSCILLATORY REGULATOR CAN SURVIVE ONE MISSION WITH OSCILLATIONS NOT NEAR THE BELLOWS NATURAL FREQUENCY OF 900 TO 935 HZ. THE TEST WAS CONDUCTED AT 640 +/- 40 HZ WITH PRESSURE OSCILLATIONS AT 100 TO 180 PSI DOUBLE AMPLITUDE.
- 3) ROCKWELL BELLOWS FATIGUE ANALYSIS WITH OSCILLATION NOT NEAR THE BELLOWS NATURAL FREQUENCY OF 900 TO 935 HZ SHOWS A 28 MISSION LIFE CAPABILITY. THE ANALYSIS WAS PERFORMED WITH 600 HZ OSCILLATIONS AT 160 PSI DOUBLE AMPLITUDE.

**GENERAL SYSTEM CONTAMINATION**

THIS FAILURE MODE HAS OCCURRED ON THIS COMPONENT DUE TO CONTAMINATION. ADDITIONALLY, GENERAL MPS SYSTEM CONTAMINATION HAS OCCURRED WHICH MAY LODGE ANYWHERE IN THE SYSTEM CAUSING THIS FAILURE MODE (REFERENCE THE FOLLOWING PARAGRAPHS).

CONTAMINATION FAILURES HAVE OCCURRED AT ALL PHASES OF MANUFACTURING AND PARTS REPLACEMENT. IN ALL CASES, STRICT ADHERENCE TO CLEANLINESS CONTROL PROCEDURES IS THE PRIMARY METHOD OF CONTAMINATION PREVENTION.

NUMEROUS LARGE PARTICLES OF BLACK RUBBER MATERIAL WERE FOUND DURING A POST FLIGHT EXAMINATION OF THE LH2 17 INCH DISCONNECT OF OV099 (FLIGHT 7, REFERENCE CAR AC9800). THE LO2 AND LH2 SYSTEMS OF ALL VEHICLES WERE EXAMINED. NO RUBBER WAS FOUND IN ANY OTHER VEHICLES. AFTER EXTENSIVE INVESTIGATION THE ORIGIN WAS NOT DETERMINED.

METAL SHAVINGS HAVE BEEN DISCOVERED IN LINES AND COMPONENTS, WHICH WAS MOST LIKELY GENERATED WHEN THEY WERE CUT OUT AND/OR REPLACED (REFERENCE CARS AC9868, A9654, AC2210, AB1706; DR AD2226). METHODS ARE BEING REVISED TO MINIMIZE PARTICLE GENERATION WHEN INSTALLING/ REPLACING COMPONENTS, LINES, AND FITTINGS REQUIRING WELDED OR BRAZED JOINTS (PRODUCT QUALITY IMPROVEMENT COUNCIL). PERSONNEL HAVE BEEN CAUTIONED. ROCKWELL PROBLEM ACTION CENTER WILL CONTINUE TO MONITOR BRAZING/WELDING REWORK CONTAMINATION. PROCEDURES ARE BEING REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
NUMBER: 03-1-0239-02**

A PIECE OF A BRAZING PREFORM LODGED IN A 2-WAY SOLENOID VALVE ON OV- 099 AT PALMDALE CAUSING A LEAKAGE FAILURE (REFERENCE CARS AC2111, AB2538). STEEL AND ALUMINUM PARTICLES CAUSED EXCESSIVE LEAKAGE ON THE 850 PSIG HELIUM RELIEF VALVE (REF CAR AC2229). FOR BOTH FAILURES CORRECTIVE ACTION WAS TO ADD SPECIAL PURGE PORTS TO THE MPS HELIUM PANEL ASSEMBLIES TO IMPROVE THE QUALITY OF FINAL CLOSEOUT BRAZES.

SEVERAL FOREIGN MATERIALS WERE INTRODUCED INTO THE MPS SYSTEM DURING MANUFACTURE AND PARTS REPLACEMENT. EXAMPLES ARE: GLASS CLOTH IN LINE TO PREVENT TRAVEL OF CHIPS DOWN LINE; POLYSTYRENE OBJECT TO HOLD VALVE POPPET OPEN WHILE PURGING; COTTON SWAB MATERIAL AND GLASS BEADS FROM CLEANING OPERATION; MISCELLANEOUS PLASTIC; FOAM; AND TAPE (REFERENCE CARS AB4751, AC2217, AC6768, AC9868, MPS3A0005, AC7912, AB0530). MATERIALS WERE REMOVED AND PERSONNEL WERE CAUTIONED. A HIGH FLOW DELTA P TEST AT PALMDALE WAS ADDED TO VERIFY THAT LINES WERE NOT PLUGGED. GRIT BLASTING (GLASS BEADS AND SAND USED TO CLEAN A LINE) IS NO LONGER PERFORMED. PROCEDURES ARE BEING REVISED TO IMPROVE CLEANLINESS MAINTENANCE DURING COMPONENT BUILD UP AND REWORK (REFERENCE MCR 12512). SUPPLIER DOCUMENTS/PROCEDURES HAVE BEEN REVIEWED AND CLEANLINESS MAINTENANCE PROCEDURES HAVE BEEN IMPROVED.

ONE PIECE OF WIRE WAS FOUND IN THE INTERNAL RELIEF VALVE OF THE LO2 PREVALVE ON OV103 (REFERENCE CAR AC9101). THE SOURCE OF THE CONTAMINATION WAS NEVER FOUND, BUT IT WAS BELIEVED TO BE FROM THE ET. OTHER CONTAMINATION HAS BEEN FOUND ON THE FEEDLINE SCREENS, SUCH AS AN UNIDENTIFIED ROUND OBJECT AND VARIOUS METALLIC PARTICLES (REFERENCE CARS AB0529 AND AB0530). SOURCE OF CONTAMINATION WAS UNDETERMINED. BORESCOPE EXAMINATIONS ARE CONDUCTED ON ALL FEEDLINE SCREENS EVERY FIFTH FLIGHT TO VERIFY CLEANLINESS. CONTAMINATION WAS REMOVED WHEN POSSIBLE.

CURRENT DATA ON TEST FAILURE, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE.

**(E) OPERATIONAL USE:**

ASCENT: PNEUMATIC HELIUM BOTTLE PRESSURE IS ON DEDICATED DISPLAY IN THE COCKPIT. CREW ACTION IS TO FOLLOW NORMAL LEAK DETECTION ISOLATION PROCEDURE. PRIOR TO MECO, ISOLATION VALVES (LV7,8) MAY BE REOPENED AND THE LEFT ENGINE HELIUM CROSSOVER VALVE (LV10) MAY BE OPENED.

PNEUMATIC TANK, REGULATOR, AND ACCUMULATOR PRESSURE ARE ON S/M ALERT FDA SYSTEM AND THE BFS SYSTEM SUMMARY DISPLAY. THIS ALLOWS THE FLIGHT CREW TO RESPOND TO A PNEUMATIC HELIUM SYSTEM LEAK INDEPENDENT OF GROUND CONTROL.

ENTRY: PROCEDURE CHANGES TO DEFEND AGAINST THIS FAILURE DURING ENTRY (NOMINAL AND ATO ONLY) ARE AS FOLLOWS:

- ACTIVATE ALL THREE ENGINE LEG "A" REGULATORS PRIOR TO VENT DOOR CLOSURE FOR DEORBIT.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE****NUMBER: 03-1-0239-02**

- ACTIVATE HARDWARE CAUTION & WARNING FOR ALL THREE ENGINE LEG "A" REGULATOR OUTLET HIGH CONDITIONS.

---

**- APPROVALS -**

---

S&R ENGINEERING	: W.P. MUSTY	:/S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	:/S/ P. A. STENGER-NGUYEN
DESIGN ENGINEERING	: CHARLES EBERHART	:/S/ CHARLES EBERHART
MPS SUBSYSTEM MGR.	: TIM REITH	:/S/ TIM REITH
MOD	: JEFF MUSLER	:/S/ JEFF MUSLER
USA SAM	: MIKE SNYDER	:/S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE